Special Session s on Climate Change, Community - Environment and Ecosystem and Environmental Pollution and Chronic Kidney Disease in North Central Province of Sri Lanka,
5th International Conference on Sustainable Built Environment 2014, Kandy, Sri Lanka,
12th to 15th December 2014

ICSBE/14/240

EFFECT OF CHEMICALS USED IN BUILDING OPERATION ON INDOOR AIR QUALITY (IAQ)

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Abstract: Better quality of air is one of the basic needs for every human being. Since the people spend most of the time inside the buildings, indoor air quality is a critical factor on occupant health. If the indoor environment is polluted, the occupants may experience number of possible health conditions such as sneezing, fatigue, headache, dizziness, nausea, irritability, and respiratory diseases as asthma. Also, long term exposure into the pollutants can cause more serious health effects. Therefore it is very important to maintain a high degree of hygienic level in all our buildings by identifying the indoor pollute sources and achieving a proper design of ventilation system in the indoor environment. The aim of this research is to find out the IAQ variation due to a selected set of chemicals used in building operation in the daily routines. The emission from the sources of mosquito coil, naphthalene ball, open waste burning (Dry leaves and Polythene) and air freshener were tested under controlled environmental conditions and a case study was carried out in a service center where a significant amount of chemicals are used in the daily activities.

Indoor Air Quality Monitor (IQM60 Environmental Monitor V5.0) and Haz-Dust Particulate Air Monitor were used to measure the concentration of Carbon Monoxide (CO), Carbon Dioxide (CO2), Nitrogen Dioxide (NO2), Total Volatile Organic Compounds (TVOCs), Particulate Matter (PM2.5), temperature and relative humidity during the experiments. The results revealed that high concentrations of TVOC inside the motor vehicle service center during the entire working hours. Therefore it is essential to consider the indoor activities during the design stage. Also, it is highlighted that the paramount importance of the proper ventilation condition since there are frequently use of indoor air pollute sources in daily usage.

Keywords: Indoor air pollution, Mosquito coil, Naphthalene ball, Open waste burning (Dry leaves and Polythene), Air freshener, Motor vehicle service center

1. Introduction

Most of us spend around 90% of our time in the indoor environment [1]. Therefore it is essential to maintain higher level of health and safety inside all types of buildings. In the last several years, the scientific evidence has indicated that the air within domestic and other buildings can be more seriously polluted than the outdoor air in most of the industrialized cities [2]. Thus, there can be several risks involved for the occupants of various types of buildings.

When we consider the modern buildings with prevailing operational practices and maintenance, there is a great possibility for the contamination of the indoor environment. Most of the indoors get polluted due to poor operational practices of both free running and air conditional buildings. Although the windows are provided in buildings according to the building regulations, the occupants do not open them daily due to various reasons such as poor micro climate around the building with dusty outdoor environments and vehicle fumes etc. Also the air conditional spaces are not well maintained by providing adequate amount of fresh air. Air conditioners should also be serviced on a proper maintenance schedule. NIOSH (National Institute for Occupational Safety and Health) looked at 500 of the first IAQ investigations that they had done and found that inadequate ventilation, contamination inside the building, and contamination from outside the building were the top three sources of IAQ problems [3].

In order to understand the indoor air pollution, it is very essential to identify causative agents and the sources of them. Sulfur Dioxide, Nitrogen Dioxide, Carbon Monoxide, Volatile Organic Compounds, Carbon Dioxide, Particulate Matter and undesirable temperature can be identified as common types of causative agents. These pollutants are caused due to combustion products, building materials, equipment used in buildings, vehicle emissions, chemicals used in maintenance, environmental tobacco smoke and polluted outdoor air. A comprehensive study is going on considering above factors on indoor air quality and their effect on sick building syndrome. This paper highlights the effect of chemicals used in building operation on IAQ; such as mosquito coil, naphthalene ball, open waste burning, air freshener and also a case study on IAQ parameters inside a motor vehicle service center. Measured quantities of dry leaves and polythene were separately burnt and investigated the effect of the emission generated from them.

2. Pollutant sources studied

2.1 Mosquito coil

Mosquito coil is widely known as efficient mosquito repellent. It is usually shaped into a spiral, and typically made from a dried paste of pyrethrum powder which is the major active ingredient of the mosquito coil and nearly used it about 0.3 -0.4% of the coil mass [4-5]. According to the Liu et al. investigation combustion of mosquito coils could generate particles containing heavy metals such as Cd, Zn and Pb, allethrin, and other organic compounds e.g. phenol and O-cresol [6-7]. Further organic compounds from mosquito coil smoke were identified from the gas chromatography – mass spectrometry [8].

2.2 Naphthalene ball

Naphthalene is a polycyclic aromatic hydrocarbon (C10H8), which may exist as white crystalline plates, balls or power which has a distinct and easily detectable odour [9]. It is a by-product of combustion of biomass and fossil fuels [10]. Naphthalene is primarily used in the production of phthalic anhydride, which is an intermediate chemical in the manufacturing of polyvinyl chloride plasticizers and pharmaceuticals [11]. Also this is widely used as a moth and insect repellent in building operational stage. Moreover Naphthalene acts as a solvent and is used in the production of automobile paint, driveway sealants, various chemicals in the dye and synthetic leather tanning industries, lubricants, motor fuel and toilet deodorizers.

2.3 Open waste burning

Open waste burning is a common method to dispose of waste, particularly in rural areas. Typical household waste burnt consists of items such as paper, cardboards, food items, plastic, leaves etc. A new study led by the National Center for Atmospheric Research (NCAR) estimates that the more than 40 percent of the world's garbage that is burnt, is emitting gases and particles that can substantially affect human health [12]. Therefore waste burning must be done with due care in order to minimize the emission from it or by adapting environmental friendly options like composting, recycling or by disposing of allowable waste materials at a licensed landfill.

2.4 Air freshener

Air fresheners are consumer products that typically emit fragrance and used in houses, offices, stores, restrooms and commonly in public bathrooms with the promise of creating a clean, healthy, and sweet-smelling indoor atmosphere. Furthermore there are broad range of air fresheners such as traditional sprays, continuous release (Outlet and battery operated), solid gel dispensers, hanging car air fresheners and potpourri.

Based on the literature review, it was found that air freshener that we commonly use is a simply mask odor with chemicals and it is failed to remove contaminants in the indoor environment. They sometimes add toxic chemicals to the atmosphere that may lead to cause severe health problems to the occupants. Mainly the levels of volatile organic compounds (VOC) increase due to some types of air fresheners. Furthermore many of these air fresheners contain Phthalates, which is a hazardous chemical known to be causing hormonal abnormalities, birth defects, and reproductive problems although it helps to enhance and maintain the smell of the air freshener. According to the state of California notes that five common types of Phthalates found in air freshener product are Di-ethyl

Phthalate (DEP), Di-n-butyl Phthalate (DBP), Di-isobutyl Phthalate (DIBP), Di-methyl Phthalate (DMP), Di- isohexyl Phthalate (DIHP) [13].

2.5 Chemical used in the building operation – A case study was carried out in a motor vehicle service center

Motor vehicle service centers generate large amount of hazardous pollutants and they have potential to cause pollution in the vicinity area due to the handling of various chemicals and the waste generation in the operational stage. Crude oil, petroleum refined products,solvents likeacetone, toluene, benzene and xylene, Trihalomethanes, Phenols, Inorganic fertilizers, Sulfides, AmmoniaandPerchlorate can be classified as the most commonly used of chemical pollutants in the motor vehicle service center [14].

3. Experimental program

In this study, Indoor Air Quality Monitor (IQM60 Environmental Monitor V5.0) and Haz-Dust Particulate Air Monitor were used to identify the air pollutants from the above sources. Indoor Air Quality Monitor was used to measure the concentrations of Carbon Dioxide (CO2), Carbon Monoxide (CO), Nitrogen Dioxide (NO2), Total Volatile Organic Compounds (TVOC), Temperature and Relative Humidity. Haz- Dust Particulate Air Monitor was used to measure the concentration of the particulate matters which are having the diameter less than 2.5µm.

There were two test chambers created in the experiments; one for the experiments on mosquito coil, naphthalene ball and air freshener (Figure 01) and other one for the open waste burning experiment (Figure 02). They were located inside the building, Department of Civil Engineering, University of Moratuwa. Since this building is older than three decays, there was no other effect from the building materials on IAQ. Therefore pollutants generated in the experiment can be entirely from the selected sources.

The case study on the IAQ inside the motor vehicle service center was done in the test chamber shown in the Figure 03.

Instruments were placed at a height of 1m from the ground to simulate the working height of an occupant seated on a chair. As the base case, the measurements were taken prior to the each experiment with the two pieces of equipment on various causative agents, inside the test chamber.

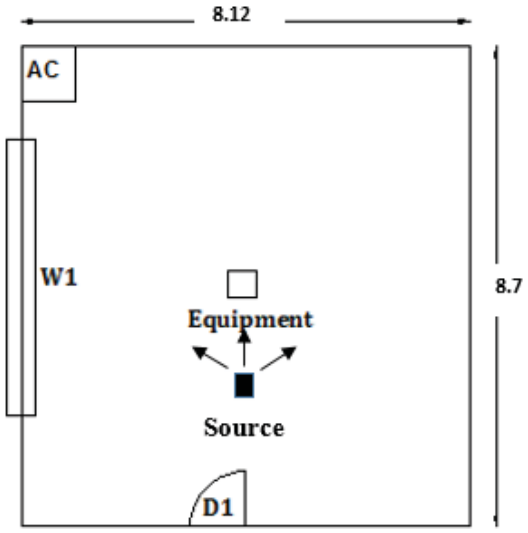

Figure 01: Plan view of the test chamber used for the experiments on Mosquito coil, Naphthalene ball and Air freshener (All the dimensions are in meters)

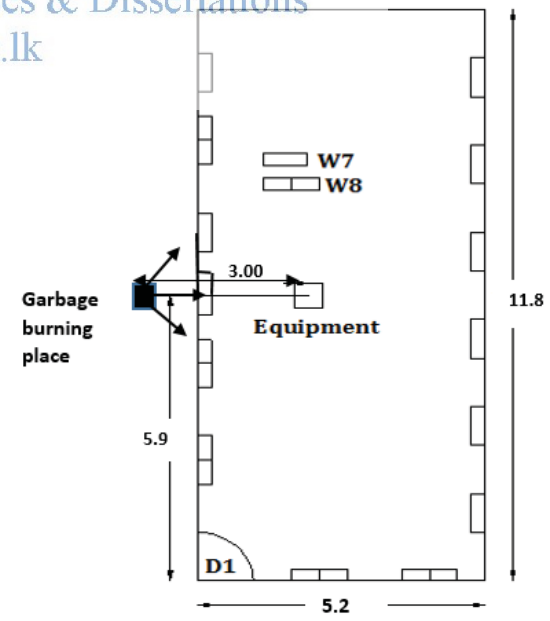

Figure 02: Plan view of the test chamber used for the experiment on open waste burning (Dry leaves and Polythene - All the dimensions are in meters)

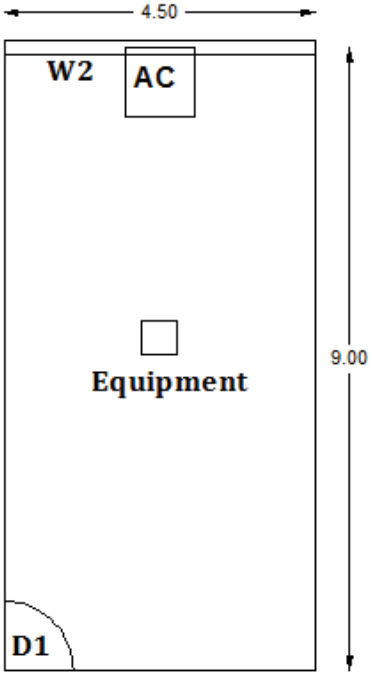

Figure 03: Plan view of the test chamber used in the motor vehicle service center (All the dimensions are in meters)

3.1 Emission from the mosquito coil

This experiment was done to investigate the effect of mosquito coil smoke on IAQ. The test chamber shown in Figure 01 was used under the minimum ventilation condition in order to witness the maximum effect from the source. The equipment was mounted at the center of the chamber and mosquito coil was kept at 0.4 m distance from the equipment over a period of 1 ½ hours.

3.2 Emission from the Naphthalene ball

This experiment was done in order to quantify the effect of smoke coming out from the burning naphthalene balls on IAQ. Same test chamber and procedure was applied as described in the experiment on mosquito coil. The commonly available standard size of two Naphthalene balls were lit and kept it 0.4m distance from the centrally mounted equipment.

3.3 Emission from the open waste burning

The test chamber shown in the Figure 02 was used for this experiment and garbage was burnt 3m distance from the equipment. The experiment was done under the natural ventilation condition and all the windows were opened and facilitated the cross ventilation across the test chamber. The measured quantities of dry leaves (2.1 kg) and Polythene (2.75 kg) were burnt separately in several days and measure the IAQ parameters from the two pieces of equipment.

3.4 Emission from the air freshener

The purpose of this experiment was to identify and quantify the indoor air pollutants generated from the air freshener usage. The experiment was done inside the test chamber shown in Figure 01 and used the traditional spray form of air freshener.

3.5 A case study on the motor vehicle service center

This experiment was carried out to identify the IAQ parameters inside the motor vehicle service center during the operation period. Figure 03 shows the plan view of the test chamber which was allocated as the workshop for the reputed motor vehicle service center in Sri Lanka. The test chamber was with air conditioned environment using the split type of air conditioner.

4. Results and Discussion

The results obtained during the experiment have shown different patterns of concentrations with time.

4.1 Emission from the mosquito coil

Chart 01 to 05 show the variation of selected pollutants due to the emission from the mosquito coil during the 1 ½ hours of operational period. According to the chart 01, the concentration of the CO has increased drastically beyond the permissible value defined by the ASHRAE (9 ppm) [15] and time taken to disperse to the ambient condition was more than 5 hours.Therefore occupants are exposed to this adverse environmental condition during this period. Since there are sever health risks from the CO exposure like reducing oxygen delivery to the body's organs and death due to the extremely high levels of CO, the occupant awareness is highly essential [16].

The concentration of NO2, CO and TVOC variation with time is shown in Chart 02, 03

and 04 respectively. According to the results, the concentrations have increased due to the mosquito coil smoke. However, it was found all the values are less than the threshold levels.

As shown in the Chart 05,the concentration of PM2.5 has increased significantly and the maximum concentration is 4 mg/m3due to the mosquito smoke over the period of 1 ½ hours. But the permissible indoor mean values defined by the World Health Organization are10µg/m3 annually and 25 µg/m3 for24 –hours [17]. Therefore toxicity index with respect to the 24-hour mean value, is 160 and the exposure time beyond the permissible value is more than 5 hours. Among the above all the pollutants, PM2.5 causes the most significant impact on human health since particle size is very small, it contains small microscopic solids or liquid droplets that they can get deep into the lungs and cause serious health problems [18].

The results shown in the Chart 01 to 05 represent the effect of mosquito coil smoke on IAQ during the 1 ½ hours of operational period. However the actual scenario could be more than this period and also the magnitudes. The result obtained from this experiment did not show any difference in the variation of temperature and relative humidity due to the mosquito smoke.

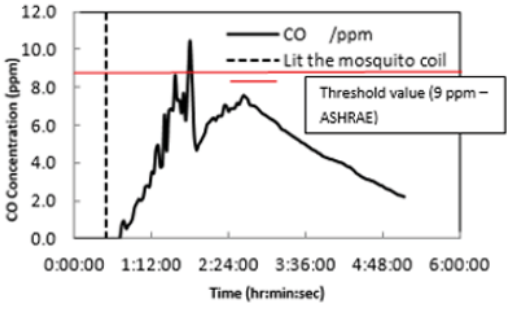

Chart 01: CO variation from the mosquito coil smoke

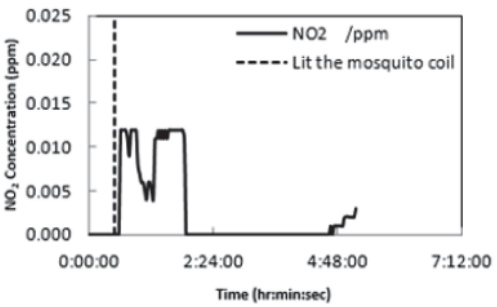

Chart 02: NO_2 variation from the mosquito coil smoke

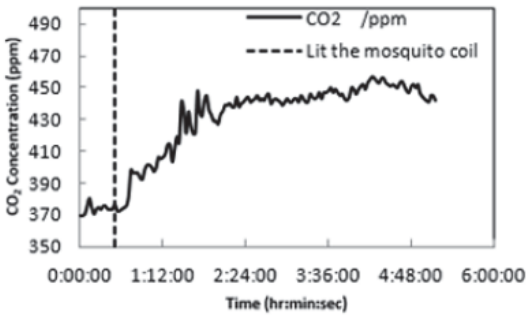

Chart 03: CO_2 variation from the mosquito coil smoke

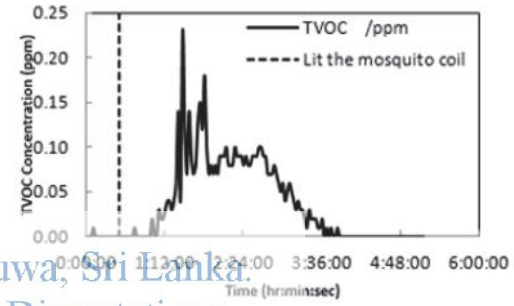

Chart 04: TVOC variation from the mosquito coil smoke

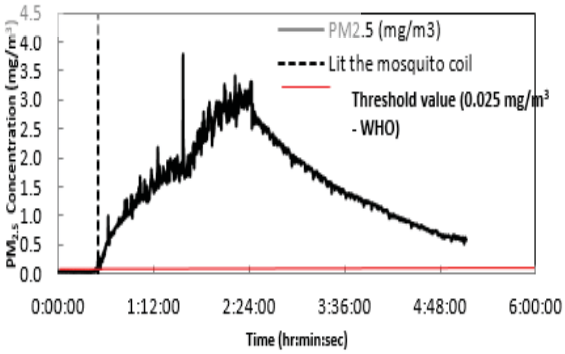

Chart 05: PM2.5 variation from the mosquito coil smoke

4.2 Emission from the Naphthalene ball

Chart 06 to 08 show the concentrations variation of TVOC, CO2 and CO from the ambient condition after burning of the two Naphthalene balls. Although the concentrations of TVOC and CO2 are well below the threshold values defined by OSHA (0.75 ppm) [19] and ASHRAE (1000 ppm) [20], the CO concentration has increased beyond the permissible value. The result obtained from this experiment did not show any difference in the variation of NO2, PM2.5, temperature and

relative humidity due to the smoke from the two Naphthalene balls.

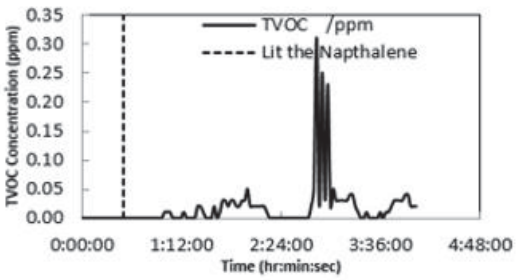

Chart 06: TVOC variation from the Naphthelene ball

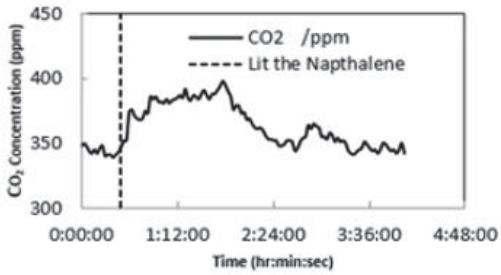

Chart 07:CO$_2$ variation from the Naphthelene ball

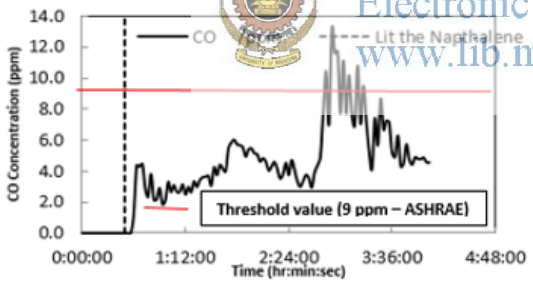

Chart 08:CO variation from the Naphthelene ball

4.3 Emission from the open waste burning

The measured quantities of 2.1 kg of Dry leaves and the 2.75 kg of polythene were used to find out the emission from the open waste burning. The obtained results are graphed in the sections of 4.3.1 and 4.3.2 for the dry leaves and polythene respectively.

4.3.1 Emission from the dry leaves burning

Chart 09 to 13, show the variation of the pollutants due the smoke coming out from the dry leaves burning. According to the charts, the concentrations of CO, TVOC and PM2.5 were increased beyond the indoor permissible values. The concentration of PM2.5 was remained the around 1 ½ hours exceeding the threshold value defined by the WHO.

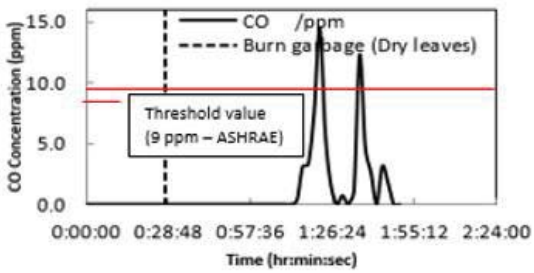

Chart 09: CO variation from the Open waste burning (Dry leaves)

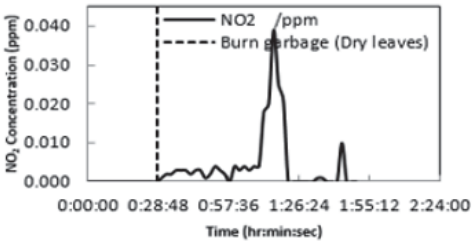

Chart 10: NO_2 variation from the Open waste burning (Dry leaves)

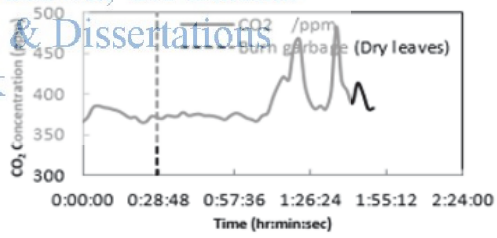

Chart 11: CO_2 variation from the Open waste burning (Dry leaves)

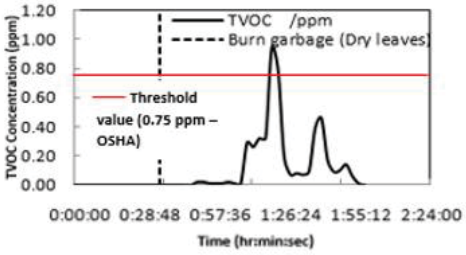

Chart 12: TVOC variation from the Open waste burning (Dry leaves)

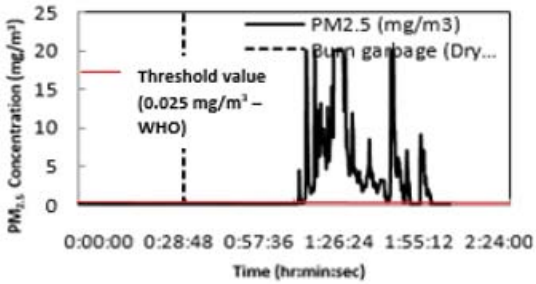

Chart 13: $PM_{2.5}$ variation from the Open waste burning (Dry leaves)

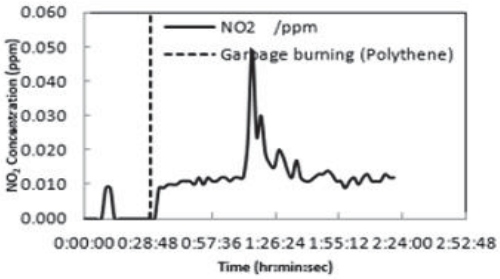

Chart 16: NO_2 variation from the Open waste burning (Polythene)

4.3.2 Emission from the Polythene burning

Same pattern of concentrations and dispersion curves were obtained for the emission from the Polythene burning. The concentrations variation of the CO, CO2, NO2, TVOC and PM2.5 were presented in the Chart 14 to 18 respectively.

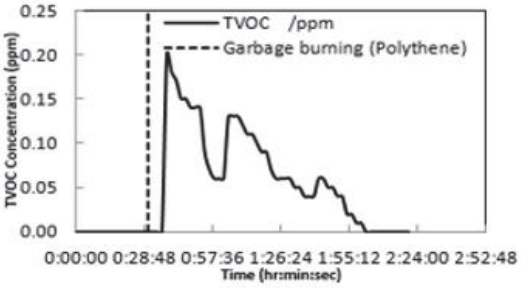

Chart 17: TVOC variation from the Open waste burning (Polythene)

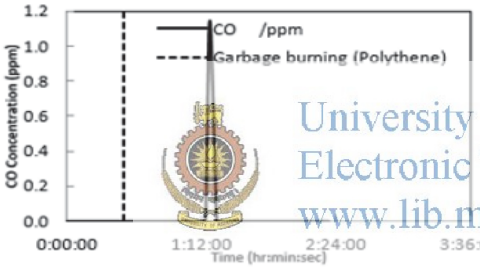

Chart 14: CO variation from the Open waste burning (Polythene)

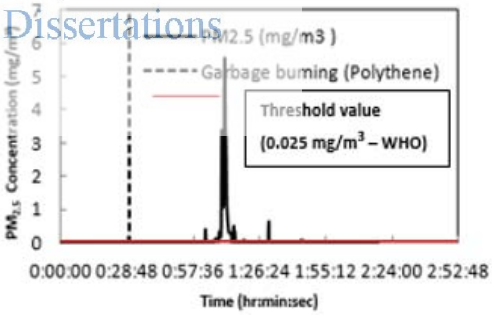

Chart 18: $PM_{2.5}$ variation from the Open waste burning (Polythene)

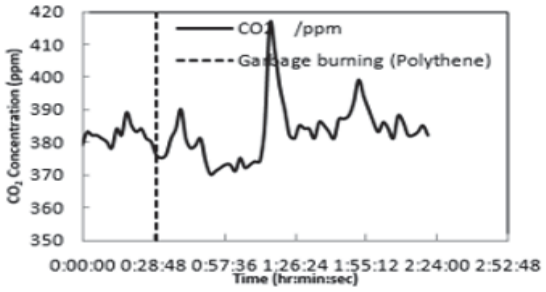

Chart 15: CO_2 variation from the Open waste burning (Polythene)

4.4 Emission from the Air freshener

Although the air freshener manufactures advertise the air freshener as the air purifier, the study revealed that the concentrations of CO, CO2 and TVOC have increased after spray the air freshener. The significant effect was observed from the TVOC concentration with considering the maximum concentration and exposure time.

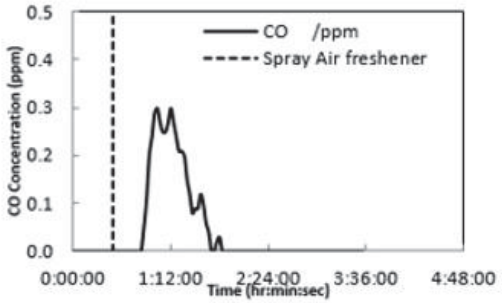

Chart 19: CO variation from the air freshener

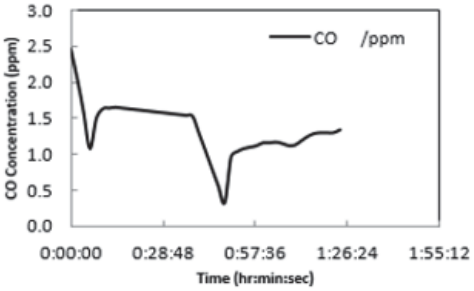

Chart 22: CO concentration inside the motor vehicle service center

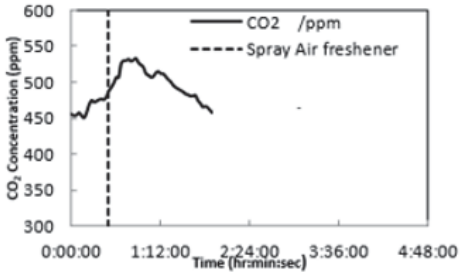

Chart 20: CO_2 variation from the air freshener

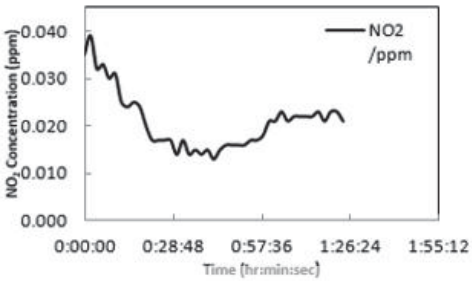

Chart 23: NO_2 concentration inside the motor vehicle service center

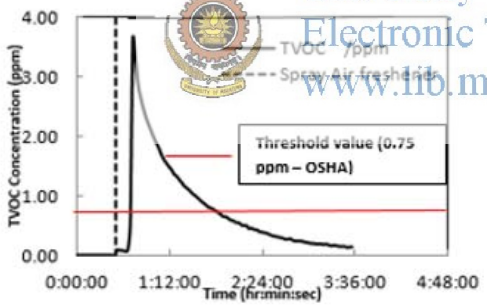

Chart 21: TVOC variation from the air freshener

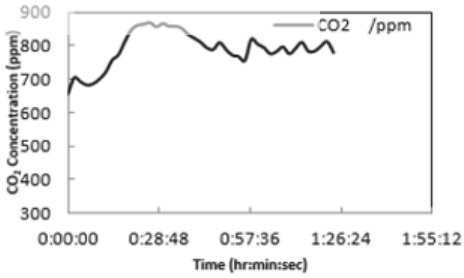

Chart 24: CO_2 concentration inside the motor vehicle service center

4.5 A case study on the motor vehicle service center

The following graphs represent the IAQ status inside the motor vehicle service center. According to the Chart 22 to 25, the concentrations of the CO and TVOC have fluctuated during the experimental period depending on the indoor activities. It was emphasized that the average indoor concentration of TVOC was 8 ppm during the entire experiment since they used to split type air conditioner without any fresh air supply.

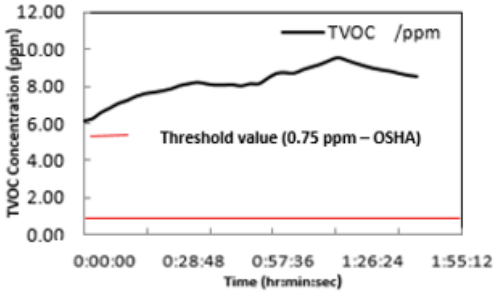

Chart 25: TVOC concentration inside the motor vehicle service center

The summary of all the experiments are listed in Table 01 with considering the maximum concentration and the exposure time of the causative agents.

Table 01: Summary of the experimental results

Causative agent / Sources	CO		CO_2		TVOC		NO_2		$PM_{2.5}$	
	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)	(i)	(ii)
Mosquito coil	**10.43**	**12 min**	**457**	**-**	**0.23**	**-**	**0.012**	**-**	**3.772**	**> 5 hours**
Naphthalene balls	**13.17**	**32**	**398**	**-**	**0.31**	**-**	**0.005**	**-**	**0.020**	**-**
Open waste burning										
▪ Dry leaves	**14.44**	**20 min**	**483**	**-**	**0.94**	**12 min**	**0.039**	**-**	**20**	**1 ½ hours**
▪ Polythene	1.12	-	416	**-**	0.2	-	0.049	**-**	**5.54**	**30 min**
Air freshener	**0.3**	-	**533**	**-**	**3.65**	**1hr 10 min**	-	**-**	-	-
IAQ inside the Motor vehicle service center	**2.46**	-	**870**	**-**	**9.53**	**Entire working hours**	**0.039**	**-**	-	-

Note:
(i) Maximum concentration
(ii) Exposure time beyond the threshold values

According to the Table 01, all the above sources generate different causative agents into the indoor environment with different magnitudes. After the comparison of their effects on IAQ by considering the maximum concentration and exposure time to the selected pollutants, it is observed that the workers in the motor vehicle service centers are exposed to the adverse environmental condition during their entire working hours. It was recorded that the high concentration of TVOC inside the workshop of the motor vehicle service centers due to the chemical used and the waste generated from the daily activities. Since the people used for the air condition environment with using split type air conditioner, there is no any fresh air rechargement into the indoor environment and most of the times maintenance of the air conditioner is also very poor. Therefore it is essential to design the any type of building by considering their indoor activities.

As in the Table 01, mosquito coil was generated high concentration of PM2.5 from 1 ½ hours of usage and the exposure period above the threshold value is also significant. When consider the actual scenario, Asian people use the mosquito coil during minimum period of 6 hours daily. Thus the actual effect from the mosquito coil could be much higher than the tabulated values.

The concentrations of PM2.5 and TVOC generated from the dry leaves burning and air freshener usage are also exceed the permissible indoor values. However the exposure time period is not significant.

5. Concluding remarks

The current trend of using chemicals in the phase of building operation and maintenance has created degraded air quality in the building. The study covered in this paper has well recorded the levels of the various pollutants and their exposure times due to a selected set of sources.

With more and more compact buildings created in the tropical climates, lack of ventilation has also been identified as another cause for poor air quality inside. This can be overcome by a proper awareness campaign on the chemicals used in building operation and also on the importance of ventilation, which could be incorporated in the building design stage.

The need for proper waste management has been identified as another essential aspect since garbage burning can pollute the environment to a greater extend.

With finding of this study building planners can confidently provide good ventilation and also the occupant can be made aware of the chemicals used in their daily routine and the severity of the emission generated from those.

Acknowledgement

The authors wish to express their sincere thanks to the Senate Research Council, University of Moratuwa for the financial support and National Research Council, Sri Lanka for their fund allocation to purchase the equipment. Also the support given by the staff of Department of Civil Engineering, University of Moratuwa is gratefully acknowledged.

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